# Practice Set: 9

Q1: Discuss the ionospheric plasma layers in earth ionosphere. [CO1]

Q2: Prove the secant law for the propagation of radio waves through earth's ionosphere. [CO3]

If we subdivide the ionosphere into many tiny layers as we did for atmospheric refraction, we can say that

$$n_0 \sin\theta_i = n_1 \sin\theta_1 = n_2 \sin\theta_2 = \cdots n_k \sin\theta_k \cdots$$

The condition for the wave to return to earth is to have total internal reflection, which begins when the refracted angle is $\theta = 90^\circ$. If this happens at the $k$th layer,

$$n_0 \sin\theta_i = n_k \sin 90^\circ = n_k$$

and since $n_0 = 1$,

$$\sin^2\theta_i = n_k^2 = \varepsilon_{r,k}. \tag{13}$$

From this, it follows that for a given angle of incidence $\theta_i$ and frequency $f_{ob}$ (where $ob$ stands for oblique incidence), the minimum electron density required to achieve total internal reflection is

$$\varepsilon_{r,k} = \sin^2\theta_i = 1 - \frac{81N_{min}}{f_{ob}^2} \tag{14}$$

If the maximum electron density present is $N_{max}$, we can also view the condition for the wave to be returned to Earth as follows. In the most challenging refraction case, normal incidence ($\theta_i = 0^\circ$, $\sin\theta_i = 0$), the only possible way for the wave to be totally internally reflected is if $\varepsilon_{r,k} = 0$. This requires the frequency to be less than the critical frequency $f_c$, given by

$$\frac{81N_{max}}{f_c^2} = 1 \Rightarrow f_c = 9\sqrt{N_{max}} \tag{15}$$

If the electron density present is $N_{max}$, (14) can be rewritten in terms of the critical frequency as follows,

$$\sin^2\theta_i = 1 - \cos^2\theta_i = 1 - \frac{81N_{max}}{f_{ob}^2} \tag{16}$$

$$f_{ob} = 9\sqrt{N_{max}}\sec\theta_i = f_c \sec\theta_i \tag{17}$$

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Q3: Discuss the cut-off condition in plasma for the propagation of an electromagnetic wave

[CO2]

Q4: Draw and discuss briefly the group and phase velocity of an electromagnetic wave propagating through ionospheric plasma

[CO2]

Q5: Discuss the communication blackout in re-entering space vehicle in terms of plasma cut-off frequency.

[CO2]

Q6:- A space capsule making a reentry into the earth's atmosphere suffers a communications blackout because a plasma is generated by the shock waves in front of the capsule. If the radio operates at a frequency of 300 MHz, what is the minimum plasma density during the blackout? [CO5]

ns Critical density

$$n_c = \frac{m \epsilon_0 \omega^2}{e^2} = \frac{m \epsilon_0 (2\pi f)^2}{e^2}$$

$$f = 300\ \text{MHz}$$